METHOD OF EXTRACTING ANTIOXIDANTS FROM LABIATE SPECIES AND THE EXTRACT PRODUCTS THEREOF

Background of the Invention

1. Field of the Invention

The invention relates generally to a method for extracting antioxidants from and, more specifically, to an improved method of extracting antioxidants from species of the family Labiatae, in particular, rosemary (*Rosemarinus officinalis*), using tetrafluoroethane based solvent blends and which yields a liquid and oily extract that is readily mixed with an edible oil for addition to animal feeds and human food.

2. Background of the Prior Art

Worldwide demand for natural antioxidants has been rising due to safety concerns about synthetic food and feed additives and the public perception that natural food and feed supplements provide certain health benefits. The most important natural antioxidants being exploited commercially today are tocopherols. Tocopherols have a potent ability to inhibit lipid peroxidation *in vivo* by trapping peroxy radicals (Burton, G. W., and K. U Ingold (1989), in Vitamin E: Biochemistry and Health Implications, edited by A. T. Diplock, L. J. Machlin, L. Packer and W. A. Pryor, The New York Academy of Sciences, New York, pp 7-22). Various herbal extracts for use as natural antioxidants are being explored. Possibilities include the extraction of rosemary or other botanical sources. Such new antioxidants may play a role in combating carcinogenesis as well as the aging process, and may be applicable in the nutraceutical industry.

Among the various natural extracts available in the market are rosemary extracts, which are reported to be highly effective in retarding lipid oxidation and protecting living cells from the damaging oxidative stress (Chen, Q., H. Shi and C-T Ho (1992), "Effects of rosemary extracts and major constituents on lipid oxidation and soybean lipoxygenase activity", J Am Oil Chem Soc 69: 999-1002; Wong, J. W., K. Hashimoto and T. Shibamoto (1995), "Antioxidant activities of rosemary and sage extracts and vitamin E in a model meat system", J Agric Food Chem 43: 2707-2712). These extracts are described as being superior to vitamin E, a well-known natural antioxidant and food supplement, in many food model systems (Lolinge, J, (1983), Natural antioxidants *in* Allen, J. C. and R. J. Hamilton eds, Rancidity in Foods, Elsevier Applied Science, London, Chapter 6). However, opposite findings are also documented. Wong *et al.* (1995) revealed that vitamin E is more effective than rosemary extract in a cooked beef homogenate. Additionally, rosemary extract is shown to be a synergist of vitamin E in stabilizing or retarding oxidation in sardine oil and fish muscle (Fang, X. and S. Wanda (1993), "Enhancing the antioxidant effect of α-tocopherol with rosemary extract in inhibiting catalyzed oxidation caused by Fe^{2+} and hemoprotein", Food Res Int 26: 405-411; Wanda, S. and X. Fang (1992), "The synergistic antioxidant effect of rosemary extract and α-tocopherol in sardine oil model system and frozen-crushed fish meat", J Food Process Preserv 16: 263-274).

As to the extraction of rosemary, many authors report that polar solvents yield extracts with higher antioxidant activities (Chang, S. S., B. Ostric-Matijasevic, C-L

Huang and OA-L Hsieh (1977), "Natural antioxidants from rosemary and sage", J Food Sci 42: 1102-1106). Chen *et al.* (1992) found that hexane extracts of rosemary contained a higher content of carnosic acid and carnosol than methanol extracts do. Carnosic acid and carnosol are the effective antioxidant molecules in rosemary. Carnosic acid and carnosol have been suggested to account for over 90% of the antioxidant activity of rosemary extracts (Aruoma, O. I, B. Halliwell, R. Aeschbach and J. Loligers (1992) "Antioxidant and pro-oxidant properties of active rosemary constituents: carnosol and carnosic acid", Xenobiotica 22: 257-268). Antioxidant molecules in general, and rosemary antioxidants specifically, are by nature labile molecules especially when exposed to heat and/or air. During the harvest, the drying, and the regular solvent extraction of rosemary some oxidation is likely to occur. Through a process of chemical reactions, carnosic acid, the naturally occurring antioxidant molecule in rosemary, is believed to be the precursor to carnosol and many other antioxidants found therein (Wenkert, E., A. Fuchs, J. D. McChesney (1965), "Chemical artifacts from the family labiate", J. Org. Chem. 30: 2931-2934). It can be demonstrated that the freshly cut leaves of rosemary do not contain carnosol (Aeschbach, R. and L. Philippossian (1993), "Carnosic acid obtention and uses", U.S. Patent No. 5,256,700). Carnosic acid is about 10 times more effective as an antioxidant than carnosol (Aruoma *et al.*, 1992) and it therefore is important for the high activity of a rosemary extract to minimize the damage to carnosic acid.

Summary of the Invention

The antioxidant activity of commercially available rosemary products were

compared with rosemary extracts prepared in the laboratory using various solvents for extraction. It was found that the antioxidant activity of commercial rosemary products was in the range of 2-5% when compared to mixed tocopherols. A methanol extract had 10% of the activity of mixed tocopherols. Methanol extraction, moreover, results in a dry powder that is difficult to dissolve into preferred carriers, such as edible oils. Accordingly, there was identified a goal to increase the specific activity of extracts of species of the family Labiate, including rosemary by optimizing the solvent extraction methodology and test alternate extraction technologies and to improve the handling characteristics of the extract.

The investigation into alternate extraction technology had two primary objectives. Firstly, to increase the specific activity of the rosemary extracts further for more efficient formulation into soybean oil or other carrier and, secondly, to identify technology allowing the removal of the essential oil fraction from the extracted material without oxidative destruction of the carnosic acid. One extraction technique investigated is based on tetrafluoroethane. Tetrafluoroethane has a boiling point of -27° C. The technology utilizes the vapor pressure of the solvent at room temperature and allows extraction under mild conditions, therefore minimizing the oxidative decomposition of carnosic acid during the extraction process. Tetrafluoroethane is substantially apolar and is preferably blended with acetone in the extractions of rosemary described here.

A process for the extraction of antioxidants from rosemary preferably meets several criteria. It should be economical and also lead to a liquid or oil extract that

can be formulated into a homogeneous, soybean oil-based final product that is largely free of odor. Methanol extracts the antioxidants from rosemary very effectively. However it leads to a dry powder extract and an inferior liquid final product after formulation into soybean oil. The extraction technology herein described is based on a solvent blend containing the solvent tetrafluoroethane (TFE) as major component. The optimum TFE-based solvent blend for the extraction of antioxidants from rosemary was identified and extraction parameters were defined. Among numerous solvent blends tested, an 80/15/5 blend of TFE/methanol/acetone, respectively, proved to be the most effective solvent resulting in a liquid extract with up to 35% of the tocopherol efficacy and an antioxidant yield of about 60% of the rosemary antioxidants.

The advantages of TFE show that it is non-flammable, has a low boiling point, is environmentally acceptable (very low toxicity), and is easily handled. It has been found that at ambient or sub-ambient temperatures, TFE leaves behind the majority of the waxes and other non-fragrant materials normally extracted with conventional solvents (Wilde P. F., 1994. Fragrance Extraction. European Patent No. 0616821A1). Another advantage with the use of TFE is that no distillation must be employed due to its low boiling point.

A purpose of the invention is to identify a solvent blend and extraction parameters for the extraction of antioxidants of rosemary while attaining a high specific activity and retaining high extraction yields.

Another purpose of the present invention is to provide a method for extracting antioxidants from rosemary that yields a liquid oily extract that is readily mixed with a

liquid product, such as soybean oil, for incorporation into animal feeds and human foods.

Brief Description of the Drawings

Fig. 1 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 2 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 3 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 4 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 5 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 6 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 7 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 8 is a chart of the antioxidant efficacy of a number of samples of rosemary extracted according to described methods.

Fig. 9 is a schematic diagram of an extraction method of the present invention.

Fig. 10 is a schematic diagram of an extraction method of the present invention.

Fig. 11 is a schematic diagram of an extraction method of the present invention.

Fig. 12 is a schematic diagram of an extraction method of the present invention.

Detailed Description of Preferred Embodiments

The invention identifies methods of extracting rosemary with different TFE-based solvents and define preferred extraction conditions. A total of 17 different solvent blends, individually and combined, were used. While the specific organic solvents of acetone, butane, hexane, and methanol were used in the blends presented in the data, other organic solvents could be employed within the scope of this invention, including but not limited to acetone, butane, ethanol, ethylene chloride, hexane, isopropanol, methanol, methylene chloride, and propylene glycol. Data presents the results of the analysis of extracts of rosemary produced from the Arp variety in terms of extraction yield (%) and percent efficacy when compared to 100% mixed tocopherols at equal applications of 500 ppm tested in chicken fat, and rosemary extract/tocopherols equivalency.

All samples were tested in untreated chicken fat at a treatment level of 500 ppm. These samples were then placed into an oxygen bomb pressurized to 50 psi with oxygen, placed in silicon oil at 100° C and allowed to oxidize. All samples were compared against the induction time of fat treated with 250 ppm 100% mixed tocopherols at a calculated equal concentration level of 500 ppm.

In the data tables, the sample number, the solvent used, percent yield, percent efficacy of tocopherols, and equivalency of rosemary extract to grams of tocopherols are reported. The percent yield was calculated by dividing the yield of rosemary extract by the initial mass of rosemary and multiplication by 100%. The percent efficacy to

tocopherols was calculated as follows:

$$\frac{(IT_{sample(500\ ppm)}-IT_{control})}{(2\ X\ (IT_{tocopherols250ppm}-IT_{control}))}\ X\ 100\%$$

where "IT" is the induction time.

Tocopherol equivalent units (g) were calculated using the assumptions that 1.0 kg rosemary was extracted according to the individual methods, and the percent yield and percent efficacy are equivalent from the small scale to the large scale extraction process:

1000 g rosemary X (% yield/100%) X (% efficacy/100%) = tocopherol equivalent (g).

The poultry fat, used as a test matrix, was supplied from Tyson. The various rosemary accessions were obtained from the Chart Co., Papa Geno's Herb Garden, and the North Carolina Botanical Garden. All solvents were purchased from Fisher Scientific Co. The apparatus that the TFE/organic experiments were conducted in was purchased from the Advanced Phytonics facility in Cowfold Grange, U.K. All rosemary leaves used in these experiments were from the Arp variety unless otherwise noted.

METHOD 1

Effect of solvent blends on efficacy

For samples 1-17 and 26, 2.0 g of dried, ground rosemary leaves were introduced into a closed glass vial extractor. The sample was then extracted with 20 g tetrafluoroethane (TFE) or a TFE/solvent mix for two hours. At this time the filtrate was quantitatively transferred into a glass collection vial. The rosemary was then washed with 10.0 g of the extraction solution for five minutes. This liquid portion was added to the first filtrate collected. The rosemary was washed a second time with 10.0 g of the

extracting solution and this was also added to the collection vial. After all of the filtrate solutions had been combined, the pressure in the vial was slowly released. After all of the TFE had evaporated, the other organic solution was removed under a stream of nitrogen gas under moderate heating. The extraction process is illustrated diagrammatically in Fig. 9.

The purpose of this series of experiments (Figure 1, samples 1-7) was to test the performance of various TFE/acetone blends for the extraction of antioxidants from rosemary. When used alone, TFE results in poor yield with low efficacy. Acetone was added in small amounts to the TFE, initially at a concentration of 5%. The efficacy of the extracts was increased dramatically, up to six-fold, when sample number 2 (95% TFE/5% acetone) was compared to the efficacy of the sample number 1 (100% TFE). As the concentration of the acetone was increased, yields increased steadily while the specific efficacy remained essentially the same after an initial steep increase. It appears that with increasing concentrations of acetone, the blend equally well extracts antioxidant components as well as non-antioxidant components. The yield data are presented in Table 1 and the antioxidant efficacy is illustrated in Fig. 1.

TABLE 1

No.	Solvent	% Yield	% Efficacy to Tocopherols	Tocopherol Equivalent Units (g)
1	100% TFE	0.95	5.84	0.555
2	95% TFE/5% acetone	3.27	35.71	11.7
3	90% TFE/10% acetone	5.06	37.01	18.7
4	85% TFE/15% acetone	6.50	35.71	23.21
5	80% TFE/20% acetone	6.11	34.41	21.0
6	75% TFE/25% acetone	6.54	34.41	22.5
7	70% TFE/30% acetone	7.49	27.92	20.9

The purpose of the next set of experiments (Figure 2, samples 1, 8-13) was to test the effect of varying the concentration of hexane when mixed with TFE. Generally, the effect of hexane added to TFE had a less pronounced effect on the performance when compared to the acetone results. However, as was observed with the acetone, hexane was also able to improve the efficacy of the extracts by five-fold when compared to sample number 1 (100% TFE). The yield data are presented in Table 2 and the antioxidant efficacy is illustrated in Fig. 2.

TABLE 2

No.	Solvent	% Yield	% Efficacy to Tocopherols	Tocopherol Equivalent Units (g)
1	100% TFE	0.95	5.84	0.555
8	95% TFE/5% hexane	1.90	24.02	4.6
9	90% TFE/10% hexane	2.79	24.02	6.7
10	85% TFE/15% hexane	4.85	24.02	11.6
11	80% TFE/20% hexane	5.69	24.02	13.7
12	75% TFE/25% hexane	5.46	26.62	14.53
13	70% TFE/30% hexane	6.40	26.62	17.0

Figures 3 and 4 (samples 2-13) compare the two different groups of solvent systems in terms of yields and specific activity. A steady increase in extraction yields can be noted as the TFE is replaced by the two solvents hexane or acetone. As to the specific activity, a rapid increase followed by a long plateau is observed. On average the TFE/acetone extracts outperformed the TFE/hexane extracts by about 10% in terms of specific activity. However, at a concentration of 30% for both solvents, the extracts were approximately equal in efficacy.

Additional solvents and solvent mixes were tested in an attempt to increase the efficacy and the total antioxidant yield extracted from the rosemary. Table 4 and Figure 5 (samples 1 and 14-17) display the results of these experiments. When a 90% TFE/10% butane blend was evaluated a three-fold increase in efficacy over sample number 1 (100% TFE) was observed. The TFE/butane extract was equal to a methanol extract. Next, several three-solvent blends were tested. The two solvents mixed with TFE were methanol and acetone, varying in concentration from 5 to 15 percent (see Table 4). Using a solvent mix of 80% TFE/15% MeOH/5% acetone, the extract obtained displayed the highest total yield with a specific efficacy of 29.22% of that of tocopherol and an extraction yield of 10.05%. Methanol in combination with acetone seems to augment extraction yields while maintaining high specific efficacy. The yield data are presented in Table 3 and the antioxidant efficacy is illustrated in Fig. 5.

TABLE 3

No.	Solvent	% Yield	% Efficacy to Tocopherols	Tocopherol Equivalent Units (g)
1	100% TFE	0.95	5.84	0.555
14	90% TFE/10% butane	NA	20.12	----
15	80% TFE/5% MeOH/15% acetone	7.85	30.52	23.9
16	80% TFE/10% MeOH/10% acetone	6.34	34.42	21.8
17	80% TFE/15% MeOH/5% acetone	10.05	29.22	29.4

METHOD 2

Effect of Multiple Extractions on Efficacy and Yield

For sample 18, 2.0 g of dried ground rosemary leaves were introduced into the glass-extracting vial. The sample was then extracted with 20.0 g of 85% TFE/15% acetone for two hours. This was repeated once more. At this time 40.0 g of the solvent mix was added to the extraction vial containing the rosemary. This was allowed to stand for 20 hours. The solvent was then removed and added to the previous two. The TFE was then allowed to evaporate off and the acetone was removed under a stream of nitrogen gas with slight heat. The process is illustrated diagrammatically in Fig. 10.

The possibility of attaining higher yields with repeated extractions while retaining the high efficacy of the extracts was explored. Figure 6 represents the antioxidant activity of sample 18. Sample 18 was produced from the repeated extraction of rosemary over a 24-hour period using 85% TFE/15% acetone. No appreciable increase in the yield or decrease in efficacy was observed when compared to a single extraction. Table 4 presents the yield data.

TABLE 4

No.	Solvent	% Yield	% Efficacy to Tocopherols	Tocopherol Equivalent Units (g)
18	85% TFE/15% acetone	6.70	33.12	22.2

METHOD 3

Effect of Extracting a Methanol Extract of Rosemary with a TFE Blend

Sample 19 was prepared by taking 100.0 g of Arp rosemary leaves and extracting it with 600 ml of methanol for 48 hours. This was then filtered and the methanol was evaporated via vacuum rotary evaporator at 40° C. Samples 20 and 22 were prepared by taking 1.0 g of sample 19 and putting it into a glass-extracting vial. For sample 20, 10 g of 85% TFE/15% acetone was added to the 1.0 g of sample 19. This solution was allowed to extract the 1.0 g sample for two hours. This solution was then filtered away from the sample. This was repeated once more. Both solutions were then combined and the TFE was allowed to boil off and the acetone was removed under a stream of nitrogen gas with slight heat. For sample 22, the same method was followed to prepare sample 20, however, instead of using 85% TFE/15% acetone as the extracting solvent, 70% TFE/30% hexane was used. The material (bagasse) that was left over from the process of preparing samples 20 and 22 was labeled 21 and 23, respectively. This process is illustrated schematically in Fig. 11.

The possibility of utilizing the TFE based extraction process to further deodorize and purify a methanol extract of rosemary was explored (see Figure 7). Methanol extracts

possess close to 100% of the antioxidants from rosemary. With this in mind, TFE mixed with an organic solvent (acetone or hexane) may separate out or extract a larger majority of the antioxidants from a methanol extract over dried, ground rosemary leaves. The test was performed with both, acetone and hexane. Initial tests indicated that the TFE blend solvent extracts were approximately equal to the methanol extracts of dried, ground rosemary. The non-extracted portion, the bagasse, left over from the TFE based extraction (samples 21 and 23), retained a large amount of the antioxidant activity which had 13.64% and 12.34%, respectively, of the tocopherol activity. This residual efficacy indicated the lack of ability of the TFE/organic solvent mix to extract 100% of the antioxidants from a methanol extract of rosemary. However, there are still many solvents and factors to be tested that will inevitably increase the efficacy as well as the extraction yield. Table 5 presents the yield data and Fig. 7 displays the antioxidant efficacy.

TABLE 5

No.	Solvent	% Yield	% Efficacy to Tocopherols	Tocopherol Equivalent Units (g)
19	100% methanol	27.66	20.13	36.0
20	85% TFE/15% acetone	3.91	38.31	15.0
21	Residue	NA	13.64	----
22	70% TFE/30% hexane	6.06	33.12	20.1
23	Residue	NA	12.34	----

METHOD 4

Extraction of Rosemary with 90%TFE/10% acetone

followed by extraction of the bagasse with methanol

Sample 24 was prepared by taking 15.0 g of ground rosemary and placing it into a 250 ml-extracting vial. To this was added 100.0 g of a 90% TFE/10% acetone solvent mixture. This was allowed to stand for two hours and then the solvent was filtered away. The TFE was allowed to boil away and the acetone was removed under a stream of nitrogen gas with slight heat. The remaining bagasse was used to create sample 25. Sample 25 was prepared in the following way. Firstly, the remaining unextracted rosemary left over from the preparation of sample 24 was put into a 250 ml flask and 60 ml of methanol was added. This was allowed to extract for 48 hours. At this point, the solution was filtered and the methanol was removed via vacuum rotary evaporator at 40° C. This process is illustrated diagrammatically in Fig. 12

Whether any residual antioxidants are left after an extraction with a TFE blend was investigated (see Figure 8). A sample of rosemary was extracted with a 90% TFE/10% acetone (sample 24) mix and the residual rosemary material was extracted with methanol (sample 25). The results indicated that a blend of TFE/10% acetone extracted approximately 30% of the antioxidants in rosemary. It appears that the presence of methanol in the solvent blend for the extraction of rosemary is critical for economical yields. The yield data are presented in Table 6 and the antioxidant efficacy displayed in Fig. 8.

TABLE 6

No.	Solvent	% Yield	% Efficacy to Tocopherols	Tocopherol Equivalent Units (g)
24	90% TFE/10% acetone	4.00	31.82	12.7
25	100% methanol	23.7	12.34	29.24

Although the invention has been described with respect to a preferred embodiment thereof, it is to be also understood that it is not to be so limited since changes and modifications can be made therein which are within the full intended scope of this invention as defined by the appended claims.